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**Constructing Agri-food Industry Input-Output Data: A Value Chain
Modelling Approach***

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Abstract

Various methods can be used to construct input-output data for sectoral modelling. These methods are broadly classified in the literature as commodity based survey, non-survey and hybrid approaches. Each approach has its own strengths and weaknesses. This paper presents an alternative approach to map the flows of goods and services. The case study of generating input-output data for agricultural industries in Western Australia is used to show how value chain modelling can accurately and reliably provide input-output data.

Keywords: Value Chain Analysis, Make Table, Use Table, Input-Output Table, Agri-food industry.

1. Introduction

The interest in regional economic development has created demands for detailed information on regional economies. To undertake consistent and comprehensive regional economic planning governments seek regional information about the economic importance of regional industries, their linkages to one another and to sectors outside the region. To obtain such information, a regional input-output model has often been used (see for example, Jensen et al. 1979; Stimson et al. 2006). The regional input-output model is a powerful tool that can be used for a wide range of economic analyses including: (i) identifying and measuring the composition and level of economic activity, (ii) understanding the inter-relationships between industries; (iii) studying the effects of changes in supply and demand throughout the economy (iv) analysing the flow of goods and services between industries and final users (v) providing the basis for the calculation and measurement of Gross Domestic Product (GDP), and (vi) studying the potential effects of policy interventions on regional income, output and employment.² However, often the regional input-output data required to form these models is conspicuously lacking, and hence has made a consistent approach to regional economic analysis a difficult task.

Over the past decades, various methods have been developed to construct regional input-output tables. These methods are broadly classified in the literature as commodity based, survey, non-survey and hybrid approaches. Each approach has its own strengths and weaknesses in terms of the logical flow of goods and services, as well as their development costs. This paper presents an alternative approach to map the flow of goods and services, using data generated from value chain modelling. A case study is illustrated whereby agri-food value chain modelling is used to generate input-output data for agricultural industries in the regional economy of Western Australia (WA).

The paper is structured as follows. Section 2 provides a brief literature review on various construction techniques for generating a regional input-output table. Section 3 presents a value chain model and illustrates the method for incorporating data generated from such a model into a regional input-output table. Section 4 provides some concluding remarks.

² Various techniques of a regional input-output analysis can be found in; for example Isard *et al.* (1998).

2. Methods of constructing a regional input-output table (RIOT)

2.1 Structure of the table

A regional input-output table represents the regional economy in terms of aggregated industries or commodity groups or sectors. The structure of the table can take the form shown in Figure 1, which is the industry by industry input-output table.

Figure 1. Structure of an Input-Output Table

	To	Intermediate demand				Final demand				Total final demand	Total supply
		Industry 1	Industry 2	.....	Industry n	Total consumption expenditure	Total capital expenditure	Changes in inventories	Exports		
From		Industry 1	Industry 2	.....	Industry n	Total consumption expenditure	Total capital expenditure	Changes in inventories	Exports	Total final demand	Total supply
Intermediate input	Industry 1 Industry 2 Industry n	Quadrant 1 Intermediate usage				Quadrant 2 Final demand					
Primary input	Compensation of employees Gross operating surplus Taxes etc. Imports	Quadrant 3 Primary inputs to Production				Quadrant 4 Primary inputs to Final demand					
	Regional production										

Note: Adapted from ABS (2000)

Quadrant 1 is usually referred to as the inter-industry transaction sub-matrix. Each column in this quadrant shows the intermediate inputs into an industry in the form of goods and services produced by other industries, and each row shows those parts of an industry's output which have been absorbed by other industries. The final demand sub-matrix shown in quadrant 2 gives the disposition of output into categories of final demand. Quadrant 3 shows entries usually referred

to as primary inputs: compensation of employees; gross operating surplus and gross mixed income; imports; and various types of taxes on production. All the primary inputs into final demand are shown in the quadrant 4.

In other words, Quadrants 1 and 2 jointly give the total usage of goods and services supplied by each industry. Total usage equals total supply because Quadrant 2 includes changes in inventories (which may be positive or negative). Quadrants 1 and 3 together show the inputs used to produce the total supply (outputs) of each industry. The sum of the inputs equals total supply (outputs) because the primary inputs in Quadrant 3 include gross operating surplus and gross mixed income (which may be positive or negative conceptually).

Various methods have been developed to derive the transaction values in quadrants 1 to 4. These methods are broadly classified as commodity based, survey, non-survey and hybrid approaches, and are discussed in the following sub-section.

2.2 Existing methods in brief

Much literature has emerged on the method of constructing a regional input-output table since its beginnings in the early 1950's. Isard (1953) and Isard and Keunne (1953) constructed regional input-output data from unadjusted national input-output coefficients. Since regional coefficients are likely to vary considerably from national coefficients, the use of unadjusted national coefficients was regarded as being highly questionable.³ Moor & Petersen (1955) used national input-output coefficients as the first approximation of regional input-output coefficients. Other authors such as Hirsch (1959), Miernyk *et al.* (1967 & 1970), Isard & Langford (1969 & 1971), Enurson & Hackman, (1971), Bourque *et al.* (1967), and Burford & Katz (1977) constructed genuine regional input-output tables primarily based on regional data. These studies have in effect generated the operating principles of the survey-based approach. This approach makes it necessary to compile the regional input-output tables by replicating the national input-output method at the regional level. The tables are built by surveying, collecting and compiling data for each region, calculating supply and use tables, then deriving input-output tables. This is basically

³ Jensen *et al.* (1979, p 30) suggested that 'the largest source of variation between region and national coefficients arises from the greater openness of regional economies; the import component of any industry will normally be much greater at the regional level than at the national level. Further, the industrial mix within any sector may vary considerably between the region and the nation, and regional technical production function may differ from those observed nationally.'

the same method as the national level input-output table compilation described in the United Nation's hand book of input-out table compilation and analysis (UN, 1999). However, some adjustments need to be made to take account of different information needs, such as inter-regional flows which can be captured in the import row and export column.

Once the supply and use table is compiled in basic price and by product-by-industry format, some coefficients of the input-output table can be calculated using the following equations: ⁴

Direct requirements coefficient sub-matrix, industry-by-industry (A_i)

$$A_i = BD \quad (1)$$

Where, $B = U\hat{g}^{-1}$ and $D = M'\hat{q}^{-1}$

U is the intermediate matrix of the use table

\hat{g} is the diagonal matrix of industry output

M is the part of the supply matrix describing domestic production

\hat{q} is the diagonal matrix of product output

Total requirements coefficient sub-matrix, industry-by-industry (T_i)

$$T_i = [I - A_i]^{-1} = [I - BD]^{-1} \quad (2)$$

Intermediate output sub-matrix, industry-by-industry (Z_i)

$$Z_i = A_i\hat{g} = BD\hat{g} \quad (3)$$

Final demand by industry (E_i)

$$E_i = DE_c \quad (4)$$

Where, E_c is final demand by commodity sub-matrix

The survey-based approach may accurately depict the economic structure but requires considerable physical and financial resources that are simply not available to most researchers or such resources are difficult to sustain on a year-to-year basis. This has resulted in the development of various non-survey and hybrid techniques. Using a survey-based approach to regularly revise a regional input-output table is an expensive pursuit.

⁴ The basic price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any tax payable, and plus any subsidy receivable, on that unit as a consequence of its production or sale. It excludes any transport charges invoiced separately by the producer.

Several systems now coexist for the production of regional tables and multipliers.⁵ One of non-survey approach is the emergence and testing of quotient type single step methods which produce a regional table as a mechanical mini-version of a national table. Jensen (1990) was of the view that this method had logical flaws and left more issues unresolved than resolved. Schaffer (1976) and Jensen *et al.* (1979) used hybrid tables based on a mixture of survey and non-survey methods. Johnson (1997) suggested a ‘distributive commodity balance (DCB)’ approach, which closely resembles the Regional Input-Output Table (R-I-O-T) Simulator developed by Schaffer and Chu (1969). The hybrid approach is often a compromise between the survey and non-survey approaches. It attempts to use the advantage of both while avoiding the main disadvantages of each. Indeed, Jensen (1990) suggested that hybrid models were the preferable future direction for developing regional tables.

The approach adopted in this study follows the Johnson’s (1997) distributive commodity balance (DCB) method in which data generated from the value chain model is used in the regional table generation procedure. This approach is explained in the following sections.

3. Incorporating the value chain data into RIOT

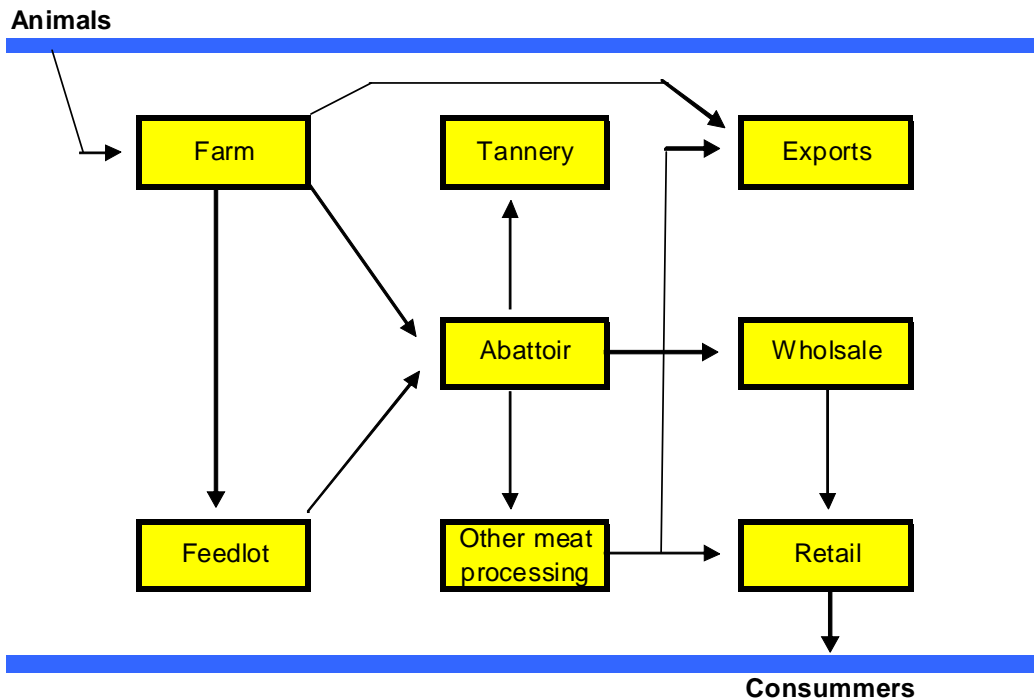
3.1 The value chain model

Drawing on the principles of regional economic modelling, Islam (1997) developed a value chain model for WA’s agri-food industries and measured the total value added contribution of individual agricultural industries to the WA economy. The model was constructed by delineating the boundary of the industry first and then identifying the chain of value adding stages of the industry. The model also describes the linkages by mapping which farm products are used as intermediate inputs to produce different final products for consumption and export. The structure is broadly divided into two components, farm and non-farm. The non-farm component then is divided into several sectors depending on the number of product transformation stages, analytical requirements and availability of data.

⁵ A detailed discussion on various non-survey approaches can be found in Jensen *et al.* (1979, pp. 30-39).

Figure 2 is an example of the flow diagram for WA’s beef industry. Each box in the diagram is considered as a value adding sector of the beef industry. The arrows indicate the movement of commodities (meat and meat by-products) among the sectors within the industry. The details of commodity flow of the WA beef industry are given in Appendix 1.

Figure 2. The Western Australia Beef Industry



By delineating the boundary of the industry, sectors identified in the flow diagram are classified as ‘sectors within-industry’. Other sectors that are not identified but may supply intermediate inputs to or buy final products from ‘sectors within-industry’ are classified as ‘sectors outside-industry’.

To estimate the industry’s valued added, it is necessary to estimate the transaction values within the ‘sectors within-industry’ and the transaction values between the ‘sectors within-industry’ and the ‘sectors outside-industry’. These transaction values can be captured using the following equations:

Total revenue equation for each sector within-industry (TR_s)

$$TR_s = \sum_{i=1}^I P_{si} Q_{si} + \sum_{f=1}^F P_{sf} Q_{sf} \quad (5)$$

Where, Q_{si} is the sale quantity of intermediate goods;
 Q_{sf} is the sale quantity of final goods;
 P_{si} is the prices of intermediate goods produced by sectors;
 P_{sf} is the prices of final goods produced by sectors.

The first argument in the RHS of equation (5) is the value of the revenue generated from the sale of intermediate goods to other sectors within industry; the second argument is the revenue received from the sale of final goods to sectors outside-industry.

Total production cost equation for each sector within-industry (TC_s)

$$TC_s = \sum_{r=1}^R P_{sr} Q_{sr} + \sum_{x=1}^X C_{sx} \bar{Q}_{sr} + w_s \bar{Q}_{sr} + k_s \bar{Q}_{sr} + v_s \bar{Q}_{sr} \quad (6)$$

Where, $\bar{Q}_{sr} = \sum_{r=1}^R Q_{sr}$.

Q_{sr} is the quantity of raw intermediate goods purchased from sectors within industry;

P_{sr} is the purchase prices of Q_{sr}

C_{sx} is the cost of x^{th} purchased inputs per unit of \bar{Q}_{sr} processed

w_s , k_s , v_s respectively are wage, rents and interest paid per unit of \bar{Q}_{sr} processed

The first argument in the RHS of equation (6) is the cost of raw intermediate goods Q_{sr} purchased from sectors within-industry; the second argument is the cost of purchased inputs x from sectors outside-industry; the third, fourth and fifth arguments are respectively total wage, rent and interests paid in processing total quantity of raw intermediate goods.

Product transformation equation

In each sector, the raw intermediate goods Q_{sr} , either individually or in combination processed are used to produce transformed intermediate Q_{si} and/or final Q_{sf} . Therefore, the product transformation equation can be expressed as follows:

$$Q_{si} \text{ \& } Q_{sf} = \phi \sum_{r=1}^R \alpha_{sr} Q_{sr} \quad (7)$$

Where, ϕ is the product transformation factor (e.g. amount of milk needed to produce 1kg butter), α_{sr} is the proportion of Q_{sr} and $\sum_{r=1}^R \alpha_{sr} Q_{sr}$ is therefore the total amount of the types of Q_{sr} used to produce intermediate Q_{si} and/or final Q_{sf} .

Finally, the industry's value added can be derived using equations (5) and (6) as follows:

The industry's value added (TVA)

$$TVA = \sum_{s=1}^S TVA_s \quad (8)$$

Where, $TVA_s = TR_s - TC_s + w_s \bar{Q}_{sr} + k_s \bar{Q}_{sr} + v_s \bar{Q}_{sr}$

Data for calculating equations (5) to (7) can be compiled from:

- Agricultural statistics published by the Australian Bureau of Statistics, e.g. ABS cat no 7121.0 and 7125.0;
- Department of Agriculture and Food Western Australia (DAFWA) economic data on commodity gross margins;
- DAFWA officers and economists; and
- Personal contacts with industry experts.

3.2 Creation of the WA input-output table

As mentioned above, the approach adopted in this study follows Johnson's (1997) DCB method.

The two key assumptions of the DCB method are:

- A regional industry uses the same production technology as the national industry as is reflected in the columns of the national input-output table.
- A regional industry has similar supply preferences to the national industry as represented by the rows of the national input-output table.

While the first assumption is common in the non-survey approaches it is the second assumption that separates the DCB method from others, such as the location quotient method and links it to the R-I-O-T methodology. The DCB method takes the national tables and creates two separate regional tables, one exhibiting the demand preference of industries, and the other their supply preference. Using the DCB method with data generated from the value chain model, the construction of WA input-output is accomplished in the following steps:

Step 1: Adjust the national demand and supply tables.

To do this it is necessary to first ensure that output or employment data for relevant industries are available at the national and regional level. This can include aggregating/disaggregating the industries in the national table or using regional industry data. These data are then used to determine the regional industry's share in the national total. Finally, the shares are used to scale the rows and columns of the national table to determine the first estimate of regional supply (regional supply table) and demand (regional demand table) respectively.

Step 2: Add regional data generated from the value chain model.

The transaction values derived in step 1 for the regional supply and demand table do not represent actual regional trade, rather what the industries would like to supply and demand if they were able to follow the national pattern. As such, data generated from the value chain model can be used to over-write the elements in the sub-matrix of those tables. This is explained in Figures 3 and 4 below.

Figure 3. The part of demand table describing demand of intermediate input

	To	Agri-food industry			the rest		
		Industry 1	.....	Industry m	Industry m+1	.....	Industry n
agri-food industry	From						
	Product 1	I			II		
						
Product m	III			IV			
.....							
Product n							
the rest							

In Figure 3, only the elements in the sub-matrices I to III can be over-written using the transaction values captured in the equations 5 and 6. The transaction values generated from the sale of intermediate and final goods can be used to replace the row entries in sub-matrix I & II. Similarly, the transaction values generated from the purchase of input (raw intermediate goods and other goods and services) can be used to replace the column entries in sub-matrix I & III. This process provides a matrix which is equivalent to the matrix U defined in the equation 1.

Figure 4. The part of supply table describing domestic production

	To	Agri-food industry			the rest		
		Industry 1	.....	Industry m	Industry m+1	.....	Industry n
agri-food industry	From						
	Product 1	I					
						
Product m				IV			
.....							
Product n							
the rest							

In Figure 4 the sale values of agri-food product can be used to replace the row entries in sub-matrix I. This provides a matrix which is equivalent to matrix M defined in equation 1.

Step 3: Derive the final table.

The transaction values and coefficients in quadrants 1 to 4 of the regional input-output table can be derived using equations 1 to 4 above. As the construction of an input-output table requires that demand and supply of commodities must be balanced, the RAS method (ABS, 1996, pp. 86-87) can then be applied to balance the rows and columns of these tables.

4. Summary and conclusion

This paper presents a new methodology for describing agricultural industries in a regional input-output table. The case study of representing agricultural industries in a regional input-output model of WA is used. Data are generated from agri-food industry value chain models. The development and updating of an agri-food industry value chain model is simple and relatively easy. Each value chain model generates the transaction data that flow from farm sector to processing, wholesale, retail, and export sectors. These data can then be used to construct the WA input-output table, using the distributive commodity balance method.

The agri-food industry valued chain model relies on already available information gathered by the Australian Bureau of Statistics and the Department of Agriculture and Food (WA). This approach ensures the WA input-output table reflects the actual economic structure of its agricultural industries. Therefore, the accuracy and quality of the coefficients derived from this table are sound.

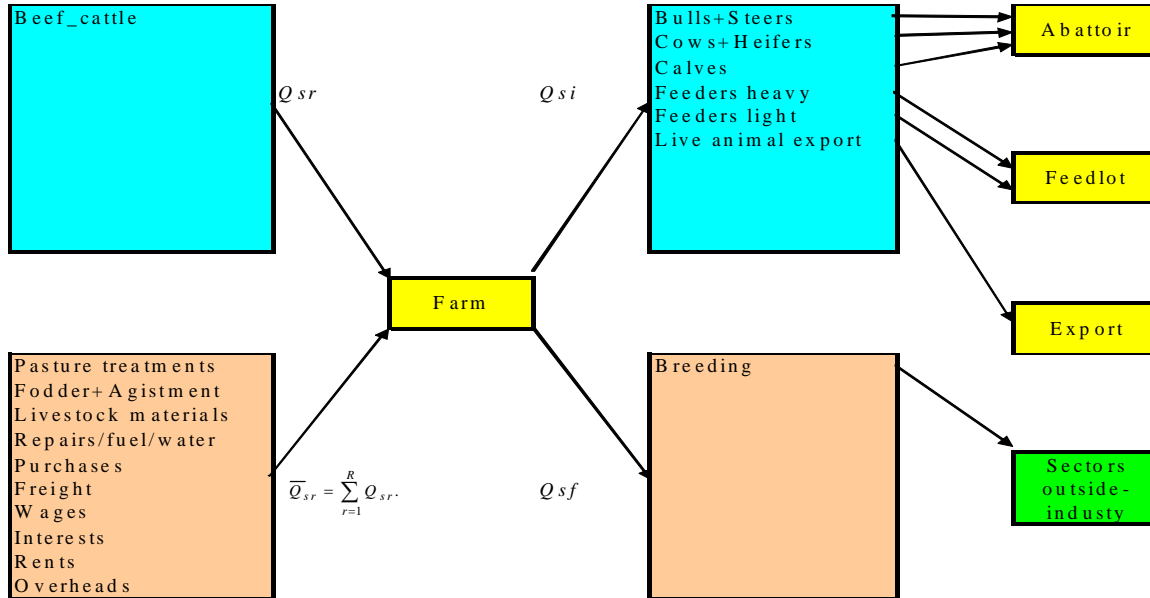
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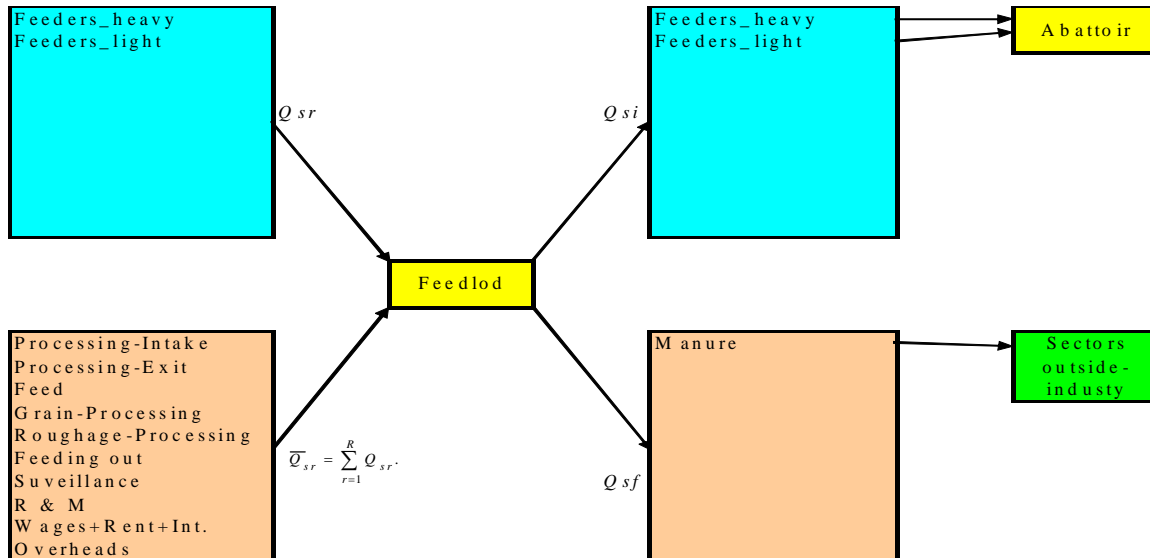
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Appendix 1. The details of commodity flow within sectors.

This appendix presents the map of commodity flow from farm to non farm sectors as shown in Figure 2 above.



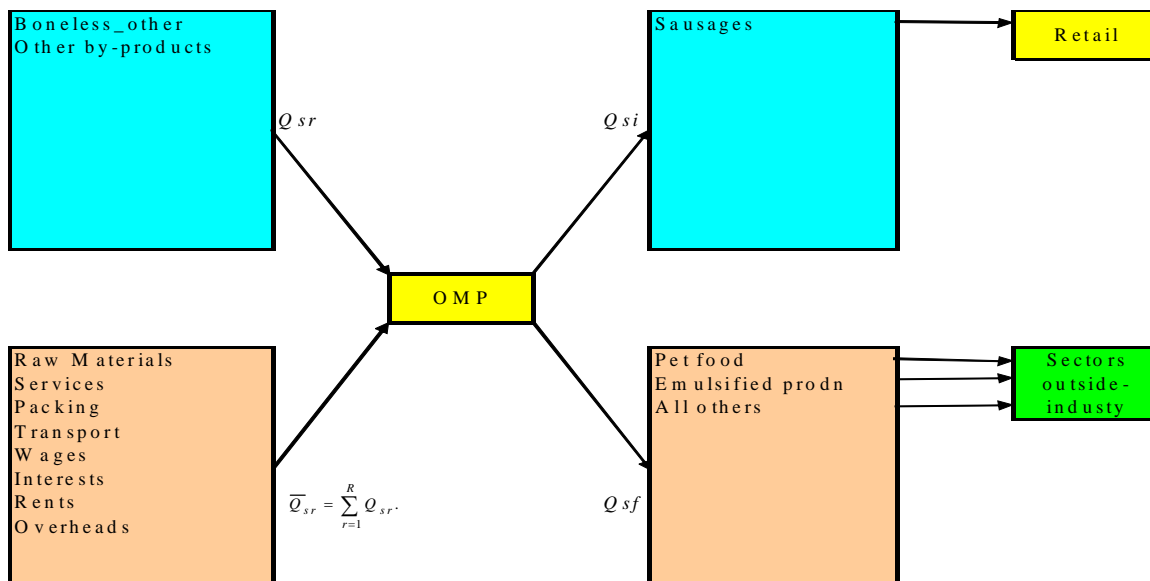
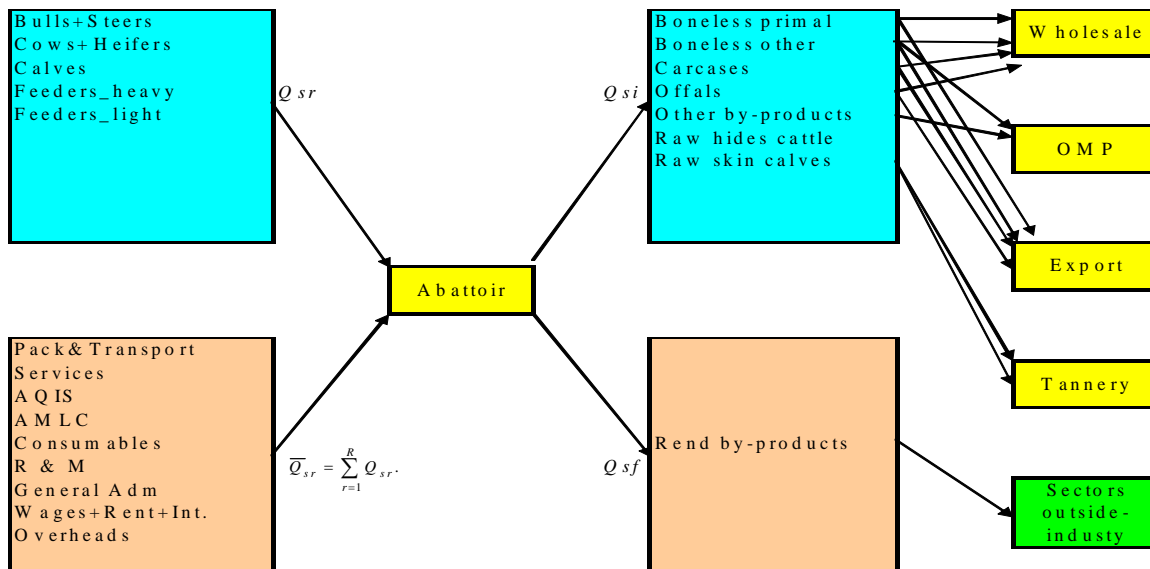
Start off with farm's revenue. Farm soles cattle as intermediate goods (Q_{si}) to abattoir, feedlot and live-animal-export sectors, and also breeding as final goods (Q_{sf}) to dairy farm which classified as sectors outside industry. As for the farm's cost, farm paid for raw material input and services which listed in the bottom-left box.

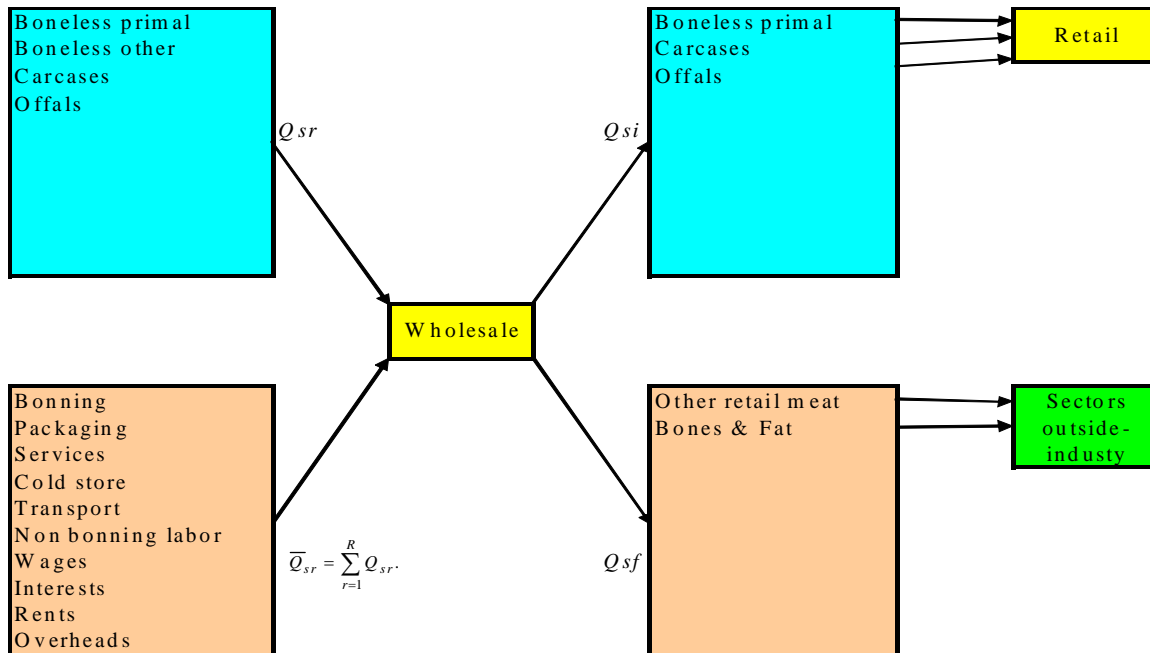


The feedlot sector bought the cattle from farm to feed them until the cattle reaches a certain weight before it is sold to abattoir. Manure from feedlot is sold to sectors that pack the manure for retail sale.

Over all, the top-left boxes listed the commodity input while the top-right listed the commodity output of feedlot sector. These two top-boxes also listed the flow of commodities among sectors within industry (sectors in box with yellow colour). The bottom-left box listed the goods and services that included in the feedlot's production cost, while the bottom-right box listed the final goods sold to other sectors outside industry. These two bottom-boxes listed the flow of commodities between the sectors within-industry and sectors outside-industry (sectors in box with light green colour).

By the same token, for the following sectors, the boxes are used to list of raw, intermediate and final commodities, while the arrows to indicate the flow of commodity, goods and services among sectors among sector within industry, and between sectors within industry and sectors outside industry.





It should be noted that the following sectors only sold final commodities to sector outside industry.

